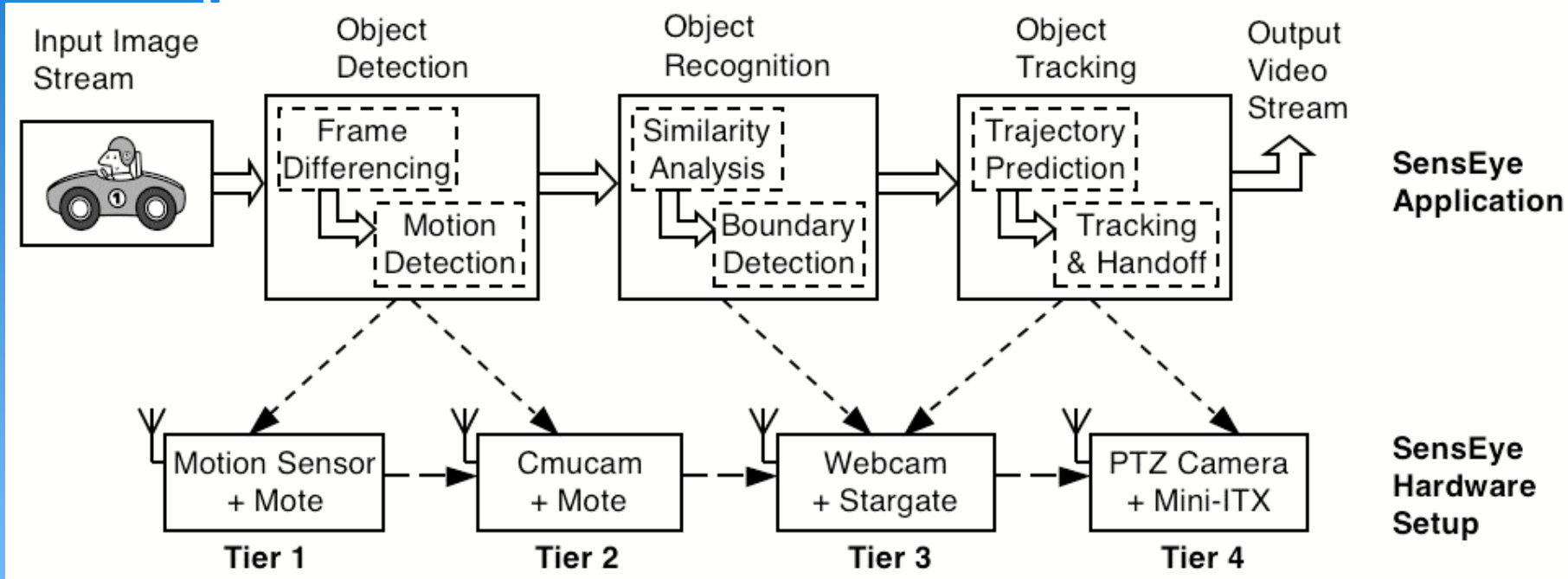
Outline

- Kulkarni, P., Ganesan, D., Shenoy, P., and Lu, Q. SensEye: a multi-tier camera sensor network. In Proceedings of the 13th Annual ACM international Conference on Multimedia (Hilton, Singapore, November 06 - 11, 2005)
  - Video sensing for environment monitoring: monitor wild-life habitats, rare species and phenology
  - Ad-hoc surveillance
  - Environment monitoring to track exotic animals
  - Search and rescue missions
  - Baby monitor (for toddlers)

System setup

- Use video sensors to track suspects
- Steps:
  - Detect objects: know that an object is there
  - Recognize objects: See if it interesting
  - Track objects: Track its motion
- Approach 1: Single tier
  - One sensor that can perform all the tasks
- Approach 2: Multi-tier
  - Three tiers in this paper where each tier has increasing amounts of resources. Judiciously mix these tiers to achieve overall benefits
- Constraints:
  - Cost (reliability and coverage) and energy consumption

Architecture



Design principles:

- Map each task to the least powerful tier with sufficient resources (and conseve energy)
- Exploit wakeup-on-demand higher tiers: (to conserve energy)
- Exploit redundancy in coverage: If two camera can see the same object, then use this fact to localize the object in order to wake up the smallest set of higher tier nodes

- Presumes good localization and calibration
  - Lower tiers need to know where the higher tiers can see. Otherwise you need to enable every sensor

Tier 1

- Lowest capability: Can perform object detection by using differencing between two frames (reference?)
  - CMUcam + mote: 136 ms (132 for camera), 13.4 J for mote and 153.8 J for camera
  - Cyclops + mote: 892 ms, 29.5 J
- Integrated platforms could be even more energy efficient

Platform	Type	Resources
Mica Mote	Atmega128 (6MHz)	84mW, 4KB RAM, 512KB Flash
Yale XYZ	OKI ArmThumb (2-57 MHz)	7-160mW, 32K RAM, 2MB external
Stargate	XScale PXA255 (100MHz–400MHz)	170-400 mW, 32MB RAM, Flash and CF card slots

Table 2: Different sensor platforms and their characteristics.

Tier 2

- Stargate
  - Webcam
  - Latency to start capture is important

1 2 3 4 5 6

Time (seconds)

Mode	Latency (ms)	Current (mA)	Power (mW)	Energy Usage(mJ)
A: Wakeup	366	201.6	1008	368.9
B: Wakeup Stabilization	924	251.2	1256.5	1161
C: Camera Initialization	1280	269.6	1348	1725.4
D: Frame Grabber	325	330.6	1653	537.2
E: Object Recognition	105	274.7	1373.5	144.2
F: Shutdown	1000	153.7	768.5	768.5
G: Suspend	–	3	15†	–

Table 5: *SensEye* Tier 2 Latency and Energy usage breakup. The total latency is 4 seconds and total energy usage is 4.71 J.

† This is measured on an optimized Stargate node with no peripherals attached.

Tier 3

- PTZ (Pan-Tilt-Zoom camera) linked to a mini-ITX embedded PC

Comparison

- Multi-tier architecture is far more energy efficient with almost similar recognition ratios

Component	Total Wakeups	On Wakeup		Energy Usage (Joules)
		Object Found	No Object Found	
Stargate 1	311	32	279	1464.8
Stargate 2	310	42	268	1460.1

Table 6: Number of wakeups and energy usage of a Single–tier system. Total energy usage of both Stargates when awake is 2924.9 J. Total missed detections are 5.

Component	Total Wakeups	On Wakeup		Energy Usage (Joules)	Cyclops Expected Energy(J)
		Object Found	No Object Found		
Mote 1	304	15	289	50.7	8.96
Mote 2	304	23	281	50.7	8.96
Mote 3	304	27	277	50.7	8.96
Mote 4	304	10	294	50.7	8.96
Stargate 1	27	23	4	127.17	127.17
Stargate 2	29	25	4	136.59	136.59

Table 7: Number of wakeups and energy usage of each *SensEye* component. Total energy usage when components are awake with CMUcam is 466.8 J and with Cyclops is 299.6 J. Total missed detections are 8.

Discussion

- The claim is not that they invented new recognition algorithms
  - On the other hand, we need recognition algorithms which may not be as accurate as the state of the art but can fit into small devices and run for long durations
- How good is this approach for ad-hoc surveillance
  - Calibration and localization requirements
    - What about latency based mis-recognition?
  - Are PTZ cameras wired or on battery?